Sound Frequency Detection Using an Ultra-Low Power MCU

Jaehoon Choi and Yongjoo Chung
Department of Electronics, Keimyung University, Daegu, South Korea
Email: kbsong11@naver.com, yjjung@kmu.ac.kr

***Abstract*—Materials made of metals have their own manifest resonant frequencies. Using this property, the quality test of products from the factory can be performed. An impact is applied to the product and the frequencies of the sound and/or vibration are measured using high-end equipment. They use a general purpose computer or a DSP (Digital Signal Processor)-based stand-alone system which is usually too large in-size to carry and expensive to build. In this paper, we introduce a system that is developed based on a MSP430 MCU (Micro Controller Unit) from TI (Texas Instrument). The ultra-low power MSP430 MCUs make it possible to make a frequency analyzer in a very small size without the need of a large-size battery. The proposed system can be used in situation where the frequency analyzer should be carried easily with an investigator and be built at low cost sacrificing some accuracy. We implemented the system using a Launchpad supplied by TI and could confirm that the proposed system could identify with a relatively high-accuracy the frequencies of various artificial and natural sounds.**

***Index Terms*—ultra-low power MCU, sound, frequency analyzer**

I. Introduction

Resonant frequencies exist associated with each body irrespective of the effects from outside. Recently, various studies have been performed using frequency analysis techniques on product design, music retrieval, brain wave detection and product investigation [1]-[6].

When the characteristic of the products from the factory deviates from normal state or the connection of the products is abnormal both due to some mistakes in the production process, the resonant frequencies deviate also from their normal ones. Using this phenomenon, we can perform product investigation using frequency analysis to detect the failure of product design or the invisible crack of the product [7]-[8].

Currently, almost frequency analyzer used for this purpose is based on hardware such as DSPs or PCs. But these devices are inconvenient to carry as they are big in size. In this study, we developed a frequency analyzer using an MSP430 ultra-low power MCU recently supplied by TI. The MSP430 MCUs are small in size and require quite a small amount of power consumption compared with conventional DSPs and micro-processors. Thus, by using a very small size of battery with the MSP430 MCUs, we can reduce the size of the hardware and make it easy to carry it and combine with other equipment.

II. Method

A. Introducing MSP430F5529

The name of the MCU used in this study is MSP430F5529. Contrary to conventional high-performance DSPs, MSP430F5529 is an ultra-low power MCU with integer type RISC (Reduced Instruction Set Computer). It has a small operating voltage in the range of 1.8~3.6 V. Despite its ultra-low power consumption, it has a maximum clock speed of 25MHz (25MIPS). In addition, it has 128KB Flash Memory and 8KB SRAM and the operating current is 7.1 mA in Active Mode with 3 V reference voltage.

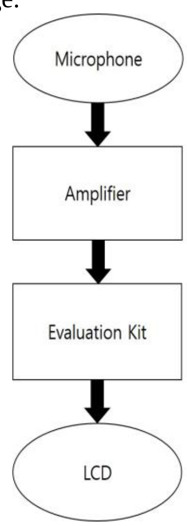

Figure 1. Structure of the overall system

B. System Architecture

In Fig. 1, we show the overall architecture of the developed system. A microphone is used as an input device for the sound signal. Amplifier passes the input sound signal to the Evaluation Kit where frequency analysis is mainly performed. The result of the frequency analysis is displayed using LCD (Liquid Crystal Display).

Fig. 2 shows the real image of the microphone used in this study. Volume-adjustable condenser microphone which has a pass-band range of 20~20,000 Hz is used.

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The value of the operating voltage can be varied by the user in the range of 3~13 V.

Figure 2. Condenser microphone (KB120)

The Amplifier circuit is designed as shown in Fig. 3. The OP AMP (TVL2760) functions as a pass-band amplification circuit which boosts low-level sound signals big enough as well as enhances the signal quality.

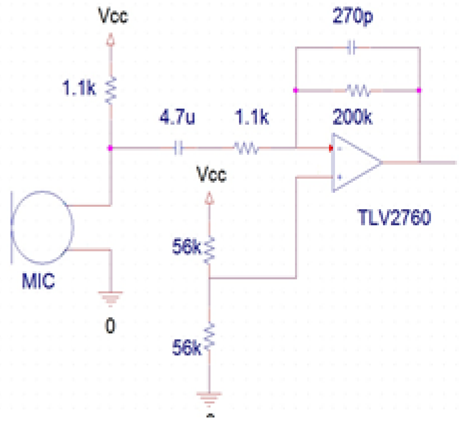

Figure 3. Amplifier circuit with a TLV2760

The amplified signal is delivered to the Evaluation Kit shown in Fig. 4. It consists of JTAG and MCU parts. MCU mainly focuses on frequency analysis after which the result is sent to LCD. JTAG is responsible for the connection with PC.

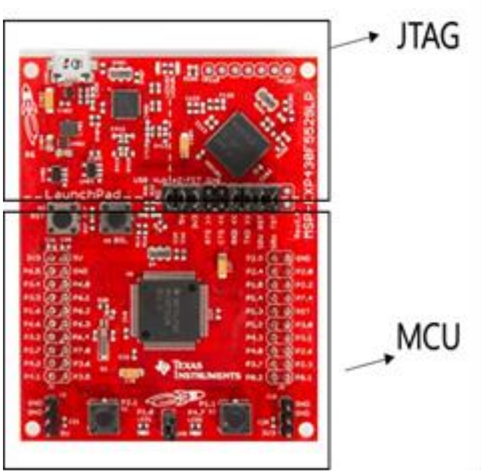

Figure 4. MSP430F5529 Evaluation Kit

Fig. 5 shows the real image of CLDC (Character Liquid Crystal Display) used in this study. The product can display 16 characters in a horizontal line and English alphabets, digits and symbols can be displayed in two vertical lines. The operating voltage is 5 V and fonts are included in itself so that ASC (American Standard Code) can be represented.

Figure 5. Character LCD (CLCD)

In Fig. 6, we show the flowchart of the frequency analysis process in the Evaluation Kit. Analog sound signal delivered to the Evaluation Kit is converted to 12 bit digital samples using ADC (Analog-Digital Converter) in the Evaluation Kit. 512-point FFT (Fast Fourier Transform) is executed and the magnitude of the FFT is used for the frequency analysis. The frequencies corresponding to the two largest magnitude FFT bins are transmitted to LCD.

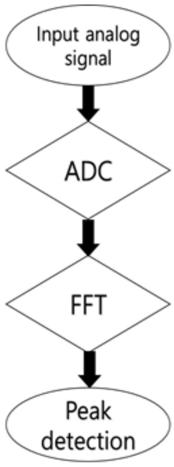

Figure 6. Frequency analysis process in the evaluation kit

C. System Development Environment

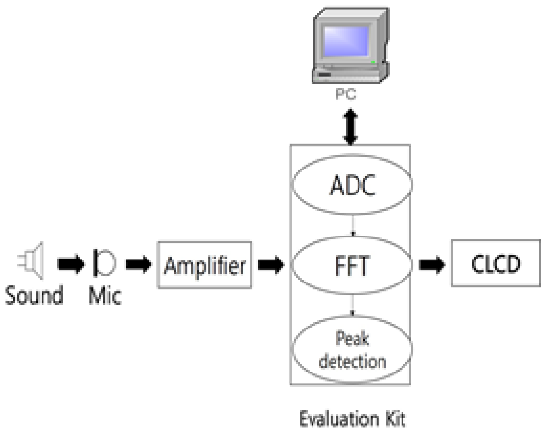

Figure 7. The overall architecture of the development system

In Fig. 7, the overall architecture of the developed system is shown. The Evaluation Kit and PC are connected with each other via JTAG which also supplies power to other peripherals (microphone, amplifier, CLCD). We can read the value of various data in the memory of MCU from PC via JTAG.

In Fig. 8, we show the real image of the developed system. We implemented the amplifier using breadboard and power is supplied to both the microphone and LCD through the Evaluation Kit.

In Fig. 9 and Fig. 10, we show the plot of the FFT magnitude for the artificially generated monotones of 400 Hz and 600Hz, respectively. Since we used 512-point FFT, the figures show symmetric architecture centered at the 256-point.

In Fig. 11, we show the plot of FFT magnitude for the waveform having two frequencies at 400 Hz and 600 Hz.

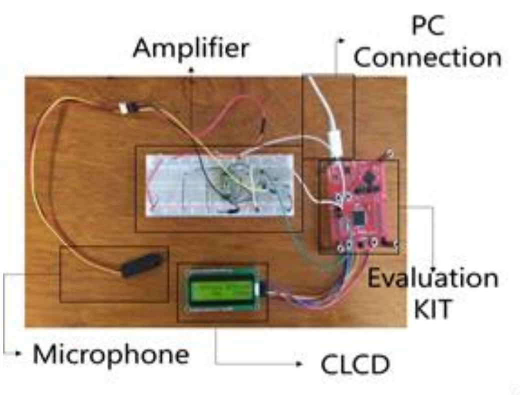

Figure 8. Real image of the development system

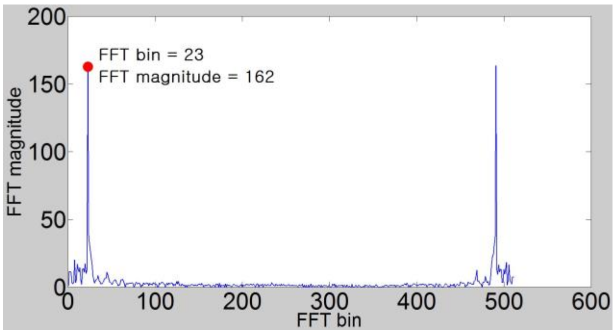

Figure 9. FFT magnitude for a 400Hz tone

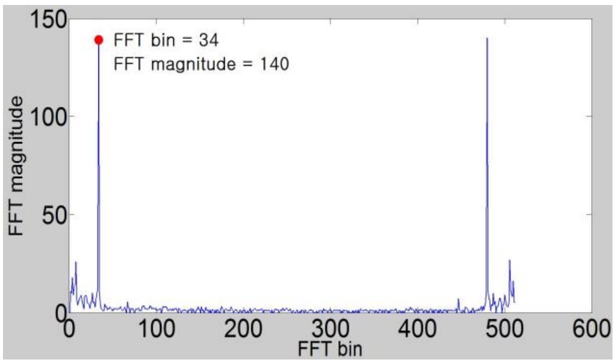

Figure 10. FFT magnitude for a 600Hz tone

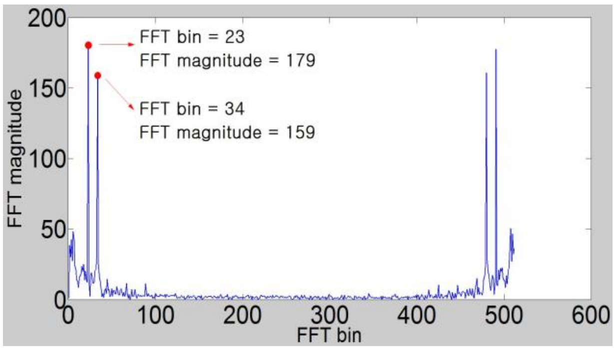

Figure 11. FFT magnitude for a 400Hz & 600Hz tone

III. Experimental Results

In this study, we generated two kinds of waveform for the experiments on frequency analysis. Four waveforms corresponding to 256Hz, 320Hz, 384Hz and 512Hz are generated using tuning forks. Waveforms corresponding to frequencies from 100Hz to 1KHz in every 100Hz are generated using a software program in smartphones.

Table I shows the results of experiments when the waveform is generated from tuning forks. As we can see from the table, about 1% of small error ratio is observed for the 256Hz, 384Hz and 512Hz signal. However, relatively large 3.8% of error ratio is observed for the 320Hz signal. The large error ratio seems tp come from the inaccurate signal frequencies from the tuning forks itself since the generated signal frequencies from the tuning forks may not be exact due to the manufacturing process of the tuning forks. Also, noises from the hardware or surrounding environment may also contribute to the large error ratio.

TABLE I. Frequency Analysis Results for the Sounds of a Tuning Fork

Tuning fork (Hz)	CLCD output (Hz)	Error ratio
256	252	1.6%
320	332	3.8%
384	378	1.6%
512	505	1.4%

Figure 12. Tuning forks and a rubber mallet

In Fig. 12, we show the real image of the tuning forks used in these experiments.

In Table II, we show the results of the frequency analysis when the sound is generated from the software program. The average error ratio is less than 1%, which accounts for the fact that the frequencies generated from software is more accurate in nature than those from tuning forks.

TABLE II. FREQUENCY ANALYSIS RESULTS FOR THE SOUNDS OF A TUNING FORK

Tone frequency (Hz)	CLCD output (Hz)	Error ratio
100	102	2.0%
200	198	1.0%
300	305	1.7%
400	396	1.0%
500	503	0.6%
600	594	1.0%
700	702	0.3%
800	792	1.0%
900	900	0.0%
1000	990	1.0%
1500	1494	0.4%
2000	1998	0.1%

IV. CONCLUSION

In this study, frequency analysis to find the natural resonant frequencies of products is performed using an ultra-low power MCU. Although conventional DSPs or PCs are doing well in this area, they are bulky and inconvenient to carry and it costs high to build such a system. However, by using the MSP430 ultra-low power MCUs as suggested in this paper, we think that the problems can be solved to a great amount. In the tests in real environments, the frequency error ratio of the developed system has been shown to be 1.1% which appears to be small enough for the system to be used for the real situations like product investigation

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Jaehoon Choi received B.Sc. and M.Sc. degrees from the Electronics, Department, Keimyung University, Daegu, South Korea, in 2014 and 2016, respectively. His research areas include digital signal processing, speech recognition and their implementation with microprocessors.

Yongjoo Chung received the B.Sc. degree in electronics engineering from Seoul National University, Seoul, South Korea in 1988 and the M.Sc. and Ph.D. degrees from the Electrical and Electronics Department, Korea Advanced Institute of Science Technology, Daejon, South Korea in 1990 and 1995, respectively. He has been with LG Electronics for 5 years developing voice mail systems. He is currently a professor at the Department of Electronics at Keimyung University, Daegu, South Korea.
His current research areas include noise robust speech recognition methods using statistical and deep learning approaches, machine learning techniques for audio event detection and digital signal processing in general.